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the **Large Hadron Collider** project

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## Interface Specification

# INNER TRIPLET FEEDBOXES: DFBX TO LQXC

***Abstract***

This specification establishes the detailed interface requirements between the DFBX and the cryomagnet assembly designated as LQXC. This specification applies to the DFBX at IR1 (left and right), IR2 (left and right), IR5 (left and right), and IR8 (left and right).

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## *History of Changes*

| *Rev. No.* | *Date* | *Pages* | *Description of Changes* |
|---|---|---|---|
| 1.0 | 23 April 2001 | All | Initial Submission |
| 1.1 | 7 June 2001 | 4 | Replaced beam tube expansion bellows with flange. |
| | | 9-12, 14 | Deleted "cryogenic" from pipe description. |
| | | 11 | Table 6.3-1, changed V flange part reference to tbd. |
| | | 4,11 | Changed reference [cc] to [bb]. |
| | | 12 | Table 6.3-2, changed to flange from bellows+flange. |
| | | 12 | Added statement on bellows and buckling precautions. |
| | | 13 | |
| | | 15 | Table 6.3-4, changed V bellows parms and added note "a". |
| | | 15 | |
| | | 15 | Deleted figure 6.4.1-1; added CERN for flange design. |
| | | 16-17 | Updated section 6.4.2 to 45-mm weld clearance. |
| | | 18 | Added "persistent ring" to section 6.4.3. |
| | | 22 | Changed to 45 & 50-mm clearances on figures 6.4.3-1,2. |
| | | | Clarified basis of O-ring design, section 6.6.1. |
| | | | Eliminated differential expansion bellows reference. |
| 1.1 | 2001-07-13 | All | Released version |

## *Table of Contents*

1. introduction

This specification establishes the detailed interface requirements between the DFBX and the cryomagnet assembly LQXC. This specification applies to all DFBX which are located at IR1 (left and right), IR2 (left and right), IR5 (left and right), and IR8 (left and right).

# 1. INTERCONNECT RESPONSIBILITIES

**Table 2-1. Interconnect components and institutional responsibilities.**

| **Component** | **Drawing Number** | **Responsible Laboratory** |
|---|---|---|
| DFBX | | LBNL |
| Pumping line bellows (XB) | 5520-MD-390065 [u] | FNAL[a] |
| Cold mass bellows (MQX1, MQX2) | 5520-MC-390073 [t] | FNAL[a] |
| Shield line bellows (Ex, E1, E2) | 5520-MD-390060 [bb] | FNAL[a] |
| Cool down bellows (LD1/LD2) | 5520-MC-390061 [s] | FNAL[a] |
| 1.9 K supply line end fitting on low side[b] (CY1) | Swagelok part number SS-1010-6 | LBNL |
| Beam tube bellows (V) | TBD | CERN |
| Beam screen | TBD | CERN |
| LQXC | | FNAL |
| Electrical soldering equipment | N/A | CERN |
| Splice kit | TBD | FNAL |
| Sliding bellows closure and flange assembly | 5520-ME-390021 [v] | FNAL |
| Beam tube flange | TBD | FNAL |
| Clam shell heat shield | TBD | FNAL |
| Pumping line and cold mass flanges | 5520-MC-390032 [w] | FNAL |
| Cool down line flange | 5520-MB-390033 [x] | FNAL |
| Shield line flanges | 5520-MB-390035 [y] | FNAL |
| Heat exchanger inner tube flange (Cy) | 5520-MB-390030 [z] | FNAL |
| Flange weld rings | 5520-XX-XXXXXX [aa] | FNAL[a] |

[a] FNAL part provided to LBNL and shipped to CERN with the DFBX.

[b] On DFBXA, C, F and G.

# 2. DFBX EQUIPMENT CODES

Because each of the eight DFBX has a unique design, equipment codes have been adopted facilitating a direct application of the LHC documentation system. In Table 3-1, “IRnR” signifies the right side of the Interaction Point n, and “IRnL” signifies the left side of Interaction Point n.

**Table 3-1. Individual DFBX Equipment Codes.**

| Location | IR1 L | IR1 R | IR2 L | IR2 R | IR5 L | IR5 R | IR8 L | IR8 R |
|---|---|---|---|---|---|---|---|---|
| Code | DFBXA | DFBXB | DFBXC | DFBXD | DFBXE | DFBXF | DFBXG | DFBXH |

# 3. CO-ORDINATE SYSTEM

The local coordinate systems used in this specification with respect to the DFBX are given in the DFBX General Interfaces Specification [1], and shown in Appendix A.

The origins of the DFBX local coordinate systems with respect to the CERN global coordinates are listed in Table 4-1. These locations are derived from the referenced CERN drawing and set the flange to flange separation between the DFBX and the LQXC to be 510 mm [a - h].

The reference local 2D-coordinate system used in this specification for the LQXC is shown in Appendix B. The longitudinal reference location for the LQXC is defined to be the plane of the LQXC flange, 510 mm from the DFBX Y-axis origin.

**Table 4-1. Position of DFBX Local Coordinate Systems**

| Code | Distance (mm) from IP | CERN Dwg. No. | Dwg. Ref. List |
|---|---|---|---|
| DFBXA | 55052 Left of IP1 | LHCLSX_0001D | [a] |
| DFBXB | 55052 Right of IP1 | LHCLSX_0002D | [b] |
| DFBXC | 55052 Left of IP2 | LHCLSX_0003D | [c] |
| DFBXD | 55052 Right of IP2 | LHCLSX_0004D | [d] |
| DFBXE | 55052 Left of IP5 | LHCLSX_0009D | [e] |
| DFBXF | 55052 Right of IP5 | LHCLSX_0010D | [f] |
| DFBXG | 55052 Left of IP8 | LHCLSX_0015D | [g] |
| DFBXH | 55052 Right of IP8 | LHCLSX_0016D | [h] |

# 4. CRYOGENIC FLOW SCHEMATICS

The cryogenic flow schematics for the LQX cryomagnets are shown on LHCDFBX_0001 [i]. This drawing shows the connection of all inner triplet superconducting magnets to the CERN cryogenic distribution line for all eight DFBX's.

The cryogenic piping connections between the DFBX and the LQX allow for:

- Thermal shield supply and return connections,
- Inner Triplet cooldown and initial filling from the low point,
- 1.9K Supply to the high end of the magnet heat exchanger,
- 1.9K return from the low end of the magnet heat exchanger, and
- Quench venting from both ends of the Inner Triplet cold mass.

The piping is consistent with the cooling requirements in the LQXC Functional Specification [2].

# 5. MECHANICAL INTERFACE

## 5.1 DRAWINGS SHOWING TRANSVERSE PIPING LOCATIONS

The transverse locations and other features of the mechanical components of the DFBX side of the DFBX-LQXC interface at room temperature are defined in the drawings listed in Table 6.1-1. The features shown in these drawings are a planar section taken at the plane of the DFBX vacuum vessel flange. Figures 6.1-1 and 2 show typical planar section views for the high and low side piping connections. The LQXC transverse piping locations are shown on the LQX drawing, "Q3 – Q2 Interconnection" [r].

**Table 6.2-1 Drawings showing DFBX Transverse Piping Dimensions and Locations.**

| Location | Drawing No. | CERN No. | Ref. Drawing List |
|---|---|---|---|
| IR1L | 24C2996 Sheet 1 | LHCDFBX_0004 | [j] |
| IR1R | 24C2986 Sheet 1 | LHCDFBX_0002 | [k] |
| IR2L | 24C3006 Sheet 1 | LHCDFBX_0006 | [l] |
| IR2R | 24C3016 Sheet 1 | LHCDFBX_0008 | [m] |
| IR5L | 24C2986 Sheet 2 | LHCDFBX_0003 | [n] |
| IR5R | 24C2996 Sheet 2 | LHCDFBX_0005 | [o] |
| IR8L | 24C3006 Sheet 2 | LHCDFBX_0007 | [p] |
| IR8R | 24C3016 Sheet 2 | LHCDFBX_0009 | [q] |

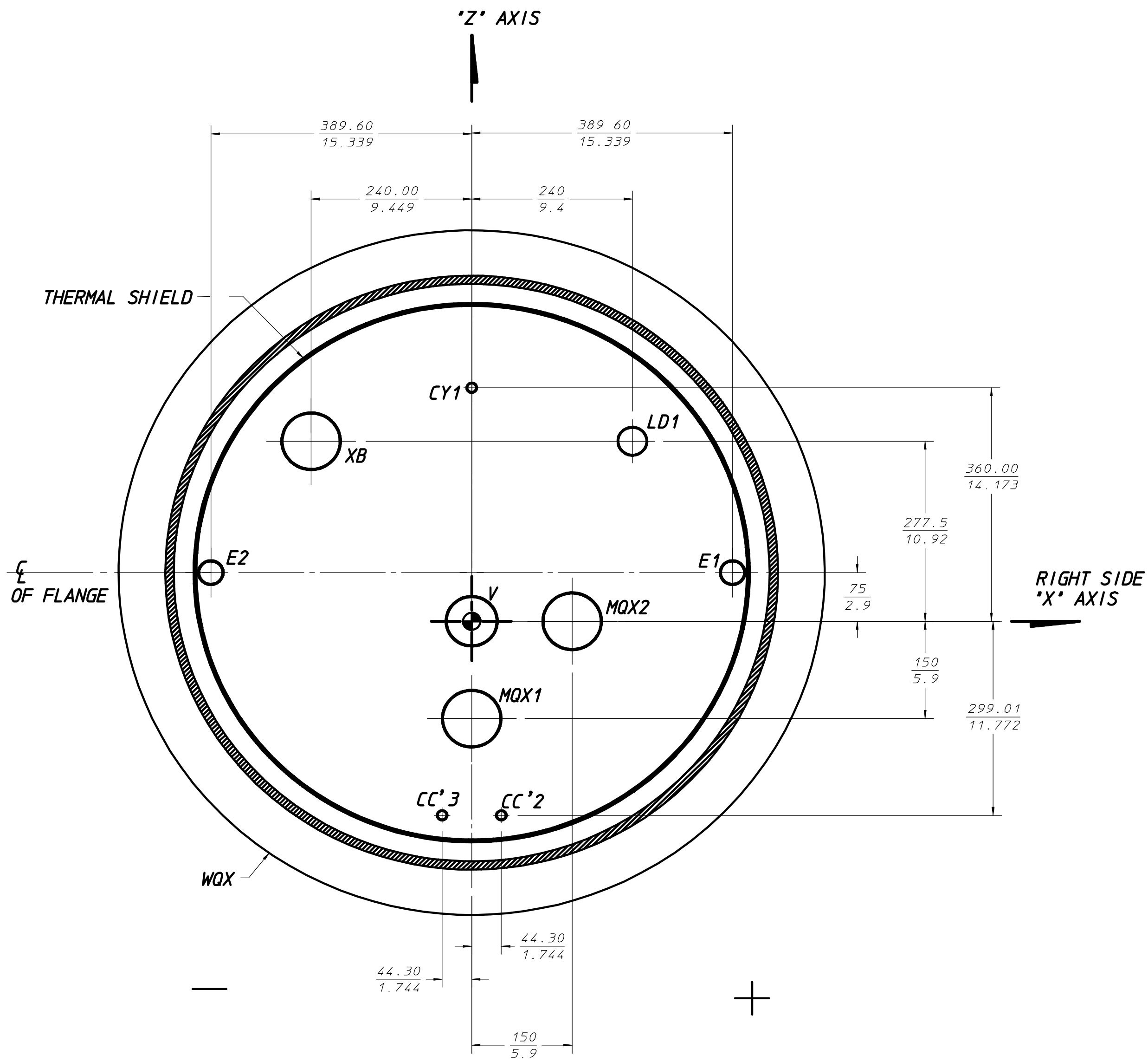



**Figure 6.1-1. Typical high-side transverse planar section at the DFBX vacuum vessel flange as seen from the LQXC. (Dimensions are mm/in; CC'2 and CC'3 not at IR2 and IR8.)**

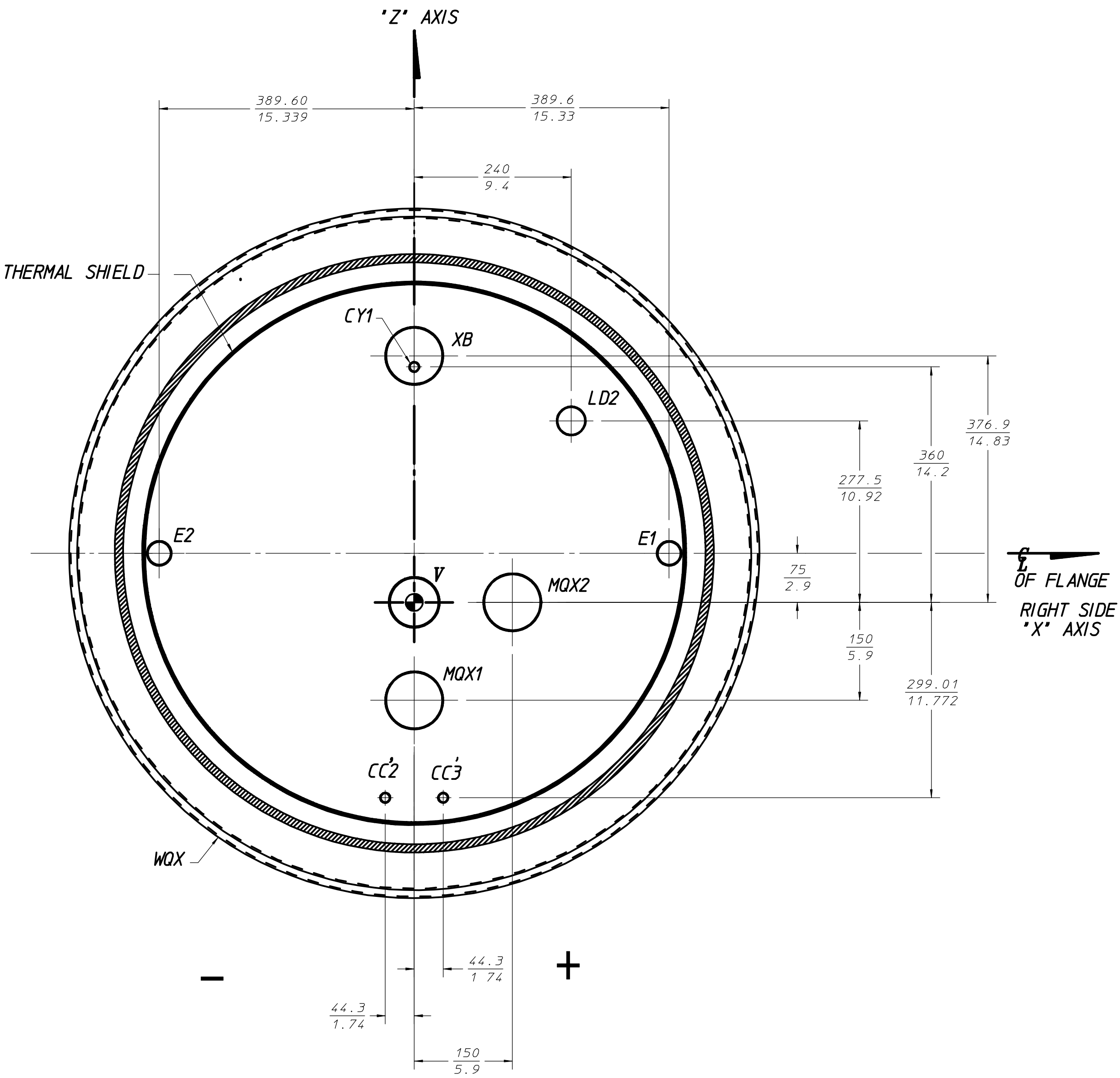



**Figure 6.1-2. Typical low-side transverse planar section at the DFBX vacuum vessel flange as seen from the LQXC. (Dimensions are mm/in; CC'2 and CC'3 not at IR2 and IR8.)**

## 5.2 PIPING IDENTIFICATION AND TRANSVERSE LOCATIONS

Table 6.2-1 lists the pipes in the DFBXA, DFBXC, DFBXF, and DFBXG. These DFBX have a lower elevation than the LQXC to which they are connected. The (x,z) co-ordinates shown are those of the pipes in the LQXC and DFBX at room temperature.

Table 6.2-2 lists the pipes in DFBXB, DFBXD, DFBXE, and DFBXH. These DFBX have a higher elevation than the LQXC to which they are connected. The (x,z) co-ordinates shown are those of the pipes in the LQXC at room temperature.

Since the method of transverse support in the DFBX is the same as in the LQXC (G-11CR spider), a similar transverse movement should occur during cool down, so no room temperature offset is needed. Calculations indicate that the transverse movement of the beam tube in the DFBX during cool down will be 0.2 mm.

**Table 6.2-1 Low-Side Piping Connections for DFBXA, C, F, and G**

| Pipe Designation | Pipe OD/ID, mm | | Pipe Co-ordinates in LQXC and DFBX at 300 K | |
|---|---|---|---|---|
| **LQXC/DFBX[a]** | **LQXC** | **DFBX** | **X[c], mm ±2** | **Z, mm ±2** |
| V | 66.7/63.0 | 78/74 | 0 | 0 |
| LD2 | 44.4/41.9 | | 240 | 277.5 |
| CC'3[b] | 15.9/13.4 | | 44.3 | -299.01 |
| CC'2[b] | 15.9/13.4 | | -44.3 | -299.01 |
| CY1 | 15.9/13.4 | | 0 | 360 |
| Ex, E2 [d] | 38.1/34.8 | | -389.6 | 75 |
| E1 | 38.1/34.8 | | 389.6 | 75 |
| MQX1 | 88.9/85.6 | | 0 | -150 |
| MQX2 | 88.9/85.6 | | 150 | 0 |
| WQX | 1055/890 | | 0 | 75 |
| XB | 88.9/85.6 | | 0 | 376.9 |

Notes:

a. Labels from LHCDFBX_0001, [i].

b. CC'3 and CC'2 are at IR1L, DFBXA, and IR5R, DFBXF, only.

c. X-signs are reversed for IR5R.

d. Pipe is named Ex in DFBXC and DFBXG, and E2 in DFBXA, DFBXF and LQXC.

**Table 6.2-2 High-Side Piping Connections for DFBXB, D, E, and H**

| Pipe Designation | Pipe OD/ID, mm | | Pipe Co-ordinates in LQXC and DFBX at 300 K | |
|---|---|---|---|---|
| **LQXC / DFBX[a]** | **LQXC** | **DFBX** | **X[c], mm ±2** | **Z, mm ±2** |
| V | 66.7/63.0 | 78/74 | 0 | 0 |
| LD1 | 44.4/41.9 | | 240 | 277.5 |
| CC'3[b] | 15.9/13.4 | | -44.3 | -299.01 |
| CC'2[b] | 15.9/13.4 | | 44.3 | -299.01 |
| CY1 | 15.9/13.4 | | 0 | 360 |
| Ex, E2 [d] | 38.1/34/8 | | -389.6 | 75 |
| E1 | 38.1/34.8 | | 389.6 | 75 |
| MQX1 | 88.9/85.6 | | 0 | -150 |
| MQX2 | 88.9/85.6 | | 150 | 0 |
| WQX | 1055/890 | | 0 | 75 |
| XB | 88.9/85.6 | | -240 | 277.5 |

Notes:

a. Labels per LHCDFBX_0001, [i].

b. CC'3 and CC'2 are at IR1R, DFBXB, and IR5L, DFBXE, only.

c. X-signs are reversed for IR5L.

d. Pipe is named Ex in DFBXD and DFBXH, and E2 in DFBXB, DFBXE and LQXC.

## 5.3 LONGITUDINAL PIPE LOCATIONS

The longitudinal interconnection regions between the LQXC and DFBX are shown on CERN layout drawings of the Long Straight Sections [a,h], with the distance between DFBX and LQXC flange set to be 510 mm. The longitudinal coordinates and the end types of the pipes are shown in Tables 6.3-1 for the DFBX and 6.3-2 for the LQXC. For those pipes that terminate in a bellows or a flexible metal hose, the coordinate given is that when the connection is made to the corresponding tube or bellows on the other side of the interconnection region.

**Table 6.3-1 Longitudinal coordinates and end types for DFBX pipes. All coordinates are measured relative to the vacuum flange WQX and all tolerances (except WQX) are ±3 mm.**

| Pipe Designation[a] | DFBX | | | |
|---|---|---|---|---|
| | Y, mm | | End type | Dwg Reference |
| | Left | Right | | |
| V | 51.6 | -51.6 | flange | tbd |
| LD1, LD2[c] | 160 | -160 | bellows+flange | [s] |
| CC'3[b] | 160 | -160 | tube end | - |
| CC'2[b] | 160 | -160 | tube end | - |
| CY1 | 160 | -160 | tube end[e] | - |
| Ex, E2[d] | 160 | -160 | bellows+flange | [bb] |
| E1 | 160 | -160 | bellows+flange | [bb] |
| MQX1 | 160 | -160 | bellows+flange | [t] |
| MQX2 | 160 | -160 | bellows+flange | [t] |
| WQX | 0 | 0 | fixed O-ring flange | [j] |
| XB | 160 | -160 | bellows+flange | [u] |

Notes:

a. Labels from LHCDFBX_0001, [i].
b. CC’3 and CC’2 are in DFBXA, B, E and F only.
c. LD1 in DFBXB, D, E and H; LD2 in DFBXA, C, F and G.
d. Pipe is named Ex in DFBXC, D, G and H, and E2 in DFBXA, B, E and F.
e. Swagelok end fitting used at DFBXA, C, F and G.

**Table 6.3-2 Longitudinal coordinates and end types for LQXC pipes. All coordinates are measured relative to the vacuum flange WQX and all tolerances (except WQX) are ±3 mm.**

| Pipe Designation[a] | LQX | | | |
|---|---|---|---|---|
| | Y, mm | | End type | Dwg |
| | Left | Right | | |
| V | -295 | 295 | flange | tbd |
| LD1, LD2[c] | -350 | 350 | flange | [x] |
| CC'3[b] | -350 | 350 | tube end | - |
| CC'2[b] | -350 | 350 | tube end | - |
| CY1 | -350 | 350 | tube end[d] | - |
| E2 | -350 | 350 | flange | [y] |
| E1 | -350 | 350 | flange | [y] |
| MQX1 | -350 | 350 | bellows+flange | [t] |
| MQX2 | -350 | 350 | bellows+flange | [t] |
| WQX | 0 | 0 | sliding O-ring flange | [v] |
| XB | -350 | 350 | flange | [w] |

Notes:

a. Labels from LHCDFBX_0001, [i].

b. CC'3 and CC'2 are at IR1 and IR5 only

c. LD1 at IR1R, IR2R, IR5L and IR8R; LD2 at IR1L, IR2L, IR5R and IR8L.

d. Swagelok end fitting used at interconnections to DFBXA, C, F and G.

Upon cooling to operational temperature, the piping connections between the LQXC and DFBX will move apart because of thermal contraction. The amount of separation is determined by the amount of temperature change, the thermal contraction coefficient, and the lengths of the pipes involved.

The expected longitudinal separation the piping in the LQX-DFBX interface is given in table 6.3-3. In the table, the free lengths are measured from the virtual interconnect plane as defined by CERN [a-h]. Bellows are required to accommodate this motion, and the column "total change" is the required stroke that the bellows must provide.

Table 6.3-4 lists the design parameters, geometry and drawing numbers of the bellows. These bellows were used to develop the layout in Section 6.4. The end treatment allows the assembly to be installed with an automatic, orbital welding machine, when space permits. All hydro-formed bellows have internal liners to prevent buckling. The welded bellows used on MQX1 and MQX2 connections are rated to withstand the internal pressures listed in Table 6.3-4.

**Table 6.3-3, Longitudinal Motion Upon Cooling To Operational Temperature**

| DFBX Pipe No. | Free Length on LQX Side (mm) | Change on LQX Side | Total Change | Change on DFBX Side | Free Length on DFBX Side (mm) |
|---|---|---|---|---|---|
| V | 6540 | 19.6 | 23.8 | 4.2 | 1398 |
| LD1/LD2 | 6540 | 19.6 | 21.4 | 1.8 | 584 |
| CC'3 | 6540 | 19.6 | 26.5 | 6.9 | 2284 |
| CC'2 | 6540 | 19.6 | 23.8 | 4.2 | 1398 |
| CY1 | 6540 | 19.6 | 21.4 | 1.8 | 584 |
| Ex, E2 | 6540 | 26.2 | 30.4 | 4.2 | 1398 |
| E1 | 6540 | 26.2 | 30.4 | 1.8 | 584 |
| MQX1 | 6540 | 19.6 | 23.8 | 4.2 | 1398 |
| MQX2 | 6540 | 19.6 | 23.8 | 4.2 | 1398 |
| XB | 6540 | 19.6 | 21.4 | 1.8 | 584 |

**Table 6.3-4, LQX-DFBX Bellows Design Parameters**

| DFBX Pipe No. | ID (mm) | OD (mm) | Int. Des. Pres. bar | Ext. Des. Pres. bar | End Tube Parameters ID x wall x length (mm) | Comp. Length (mm) | Free Length (mm) | Reqd Stroke (mm) | Ref. Dwg. List |
|---|---|---|---|---|---|---|---|---|---|
| V[a] | 79.2 | 124 | 0 | 6 | tbd | Tbd | tbd | 23.8 | tbd |
| LD1/LD2 | 57.2 | 73.7 | 20 | 6 | 57.2 x 0.889 x 42.4 | 133.4 | 152.4 | 21.4 | [s] |
| CC'3 | | | | | Expansion Loop | | | 26.5 | |
| CC'2 | | | | | Expansion Loop | | | 23.8 | |
| CY1 | | | | | Expansion Loop | | | 21.4 | |
| Ex/E2 | 39.3 | 63.0 | 22 | 6 | 39.0 x 0.889 x 42.4 | 133.4 | 152.4 | 30.4 | [bb] |
| E1 | 39.3 | 63.0 | 22 | 6 | 39.0 x 0.889 x 42.4 | 133.4 | 152.4 | 30.4 | [bb] |
| MQX1[b] | 101.6 | 124.5 | 20 | 1 | 134 OD x 101.6 ID [c] | 57 | 127.0 | 23.8 | [t] |
| MQX2[b] | 101.6 | 124.5 | 20 | 1 | 134 OD x 101.6 ID [c] | 57 | 127.0 | 23.8 | [t] |
| XB | 101.6 | 127.0 | 4 | 6 | 101.6 x 0.889 x 42.4 | 133.4 | 152.4 | 21.4 | [u] |

Notes:

a. CERN bellows yet to be designed; minimum OD recommended by I. Collins.

b. Two bellows required for each interconnect.

c. No end tube; flange welded to bellows.

## 5.4 PIPING CONNECTION DETAILS

Figure 6.4-1 shows the DFBX-LQXC interconnection for pipes MQX1, V and XB. The connections shown are typical of all weld ring flange connections.

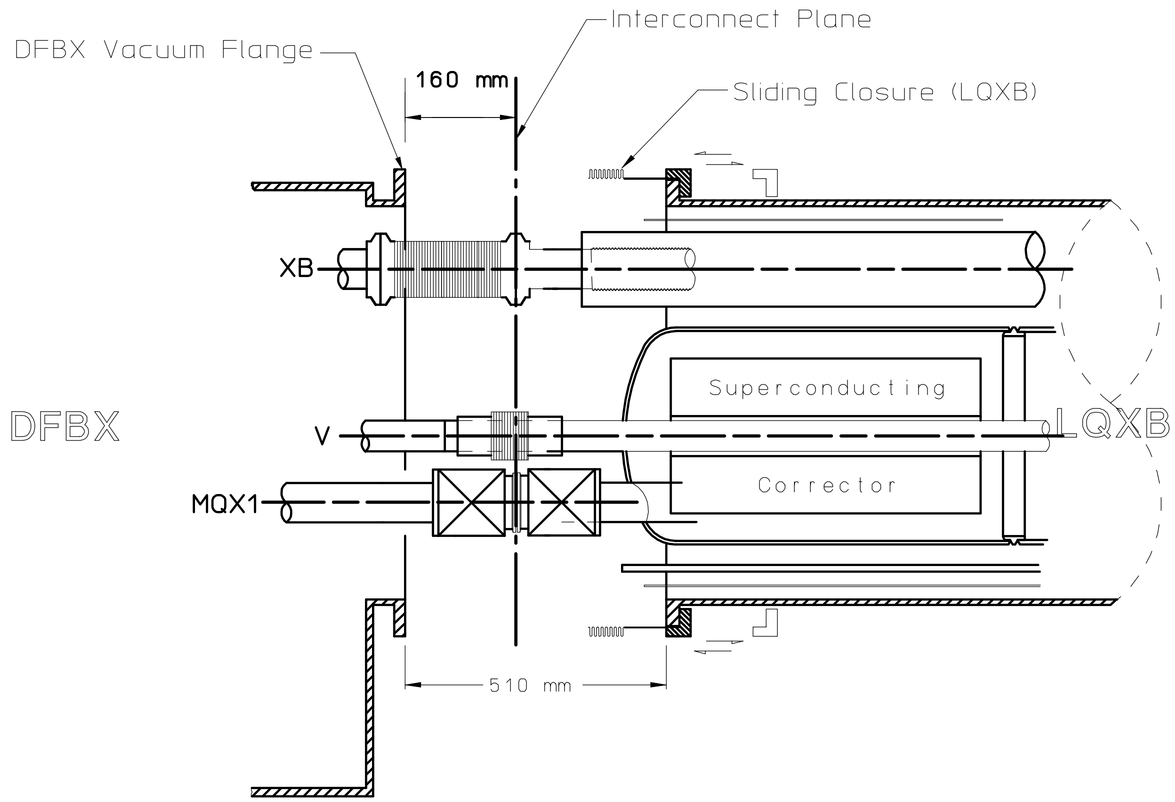



**Figure 6.4-1 DFBX-LQXC Connection Layout for MQX1, V, and XB**

### 5.4.1 BEAM TUBE CONNECTION

The DFBX bore tube will extend 51.6 mm from the vacuum box flange on the LQXC side to accommodate the beam tube bellows, RF sliding joint and beam screen to be provided by CERN. The DFBX bore tube will be fitted with a CERN-approved weld flange; flange dimensions will be determined once the interconnect design has been resolved by CERN. Further information on the space allocations for the DFBX – beam tube interfaces are given in LHC-DFBX-ES220 [4]. CERN will provide the bellows for the beam tube connection. (See Table 2-1.) Table 6.3-4 gives the minimum OD for the beam tube bellows. Although the radial clearance envelope for automatic welding tube V appears insufficient in Figure 6.4.3-1 and 2, there should be just adequate clearance (about 45 mm) as the bore tube to bellows connection is made at 51.6 mm from the DFBX exit flange, ahead of the bellows on the MQX1 and MQX2 lines.

### 5.4.2 BUS DUCT CONNECTION

The welded-metal bellows used to close the bus duct MQX1 is shown in Figure 6.4-1. Together, the pair of bellows can be opened 200 mm wide to create a chamber where the electrical connections are made in the bus bars. See Section 7.2 for details of the electrical connection. A CERN automatic or hand welding machine is required to make the closure weld between the bellows. To preserve radial space for the weld connections on the MQX1 and MQX2 lines, these connections should be made prior to making the bore tube weld connection. Note that the MQX2 line is not shown, but it is at the same radial distance from V as MQX1 and is at the same elevation as pipe V. 45-mm clearances are tight for the MQX1 and MQX2 connections but since these are double-bellows connections, it should be possible to gain the necessary clearance by moving the bellows slightly away from the cold bore tube.

### 5.4.3 MISCELLANEOUS PIPING CONNECTIONS

The XB, LD1, LD2, EX and E2 connections will be made using a CERN automatic or hand welding machine. The LD and E connections are similar to the XB connection, with the bellows installed on the DFBX side. DFBX pipe-welding clearance envelopes are shown in Figure 6.4.3-1 and 6.4.3-2. The same radial clearances exist on the LQXC side. Longitudinal clearances accommodate the 130 mm minimum distance required for the automatic welder. Flanges and bellows are as called out in Section 2 and Table 6.3-2. The TAS cooling lines, CC’2 and CC’3, and the stand-alone CY1 will be welded as in the QRL [3] and an automatic or hand welder. When CY1 is contained inside pipe XB, (on the low-side DFBXA, C, F, and G), the connection will be made using a Swagelok tube fitting.

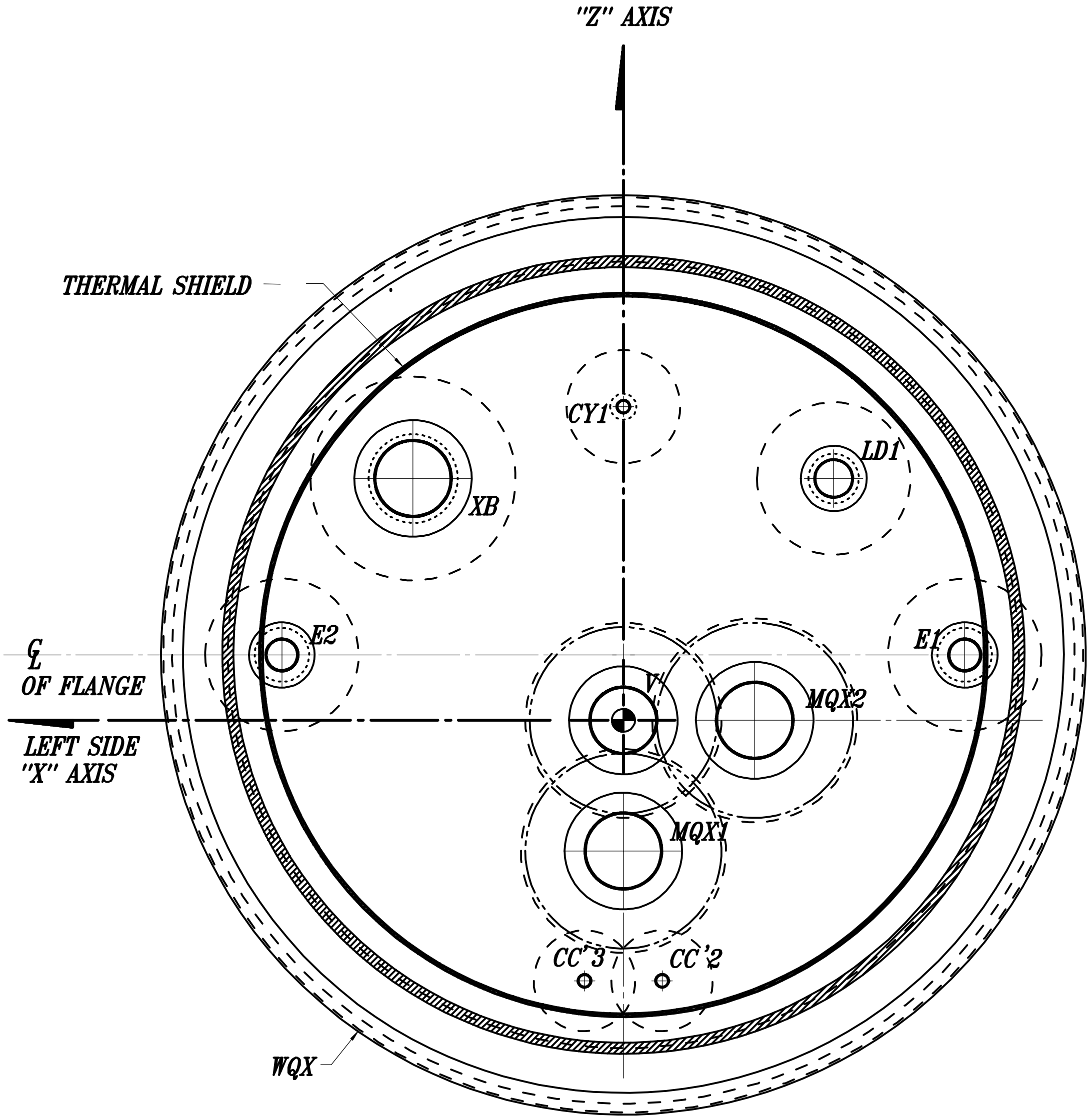



**Figure 6.4.3-1. DFBX (high-side) 50-mm automatic orbital welder clearance envelopes shown as dashed lines between flanged pipe ends for piping weld connections at interconnect plane. 45-mm clearance also shown for V, MQX1 and MQX2. (Thermal shield does not extend into interconnect region.)**

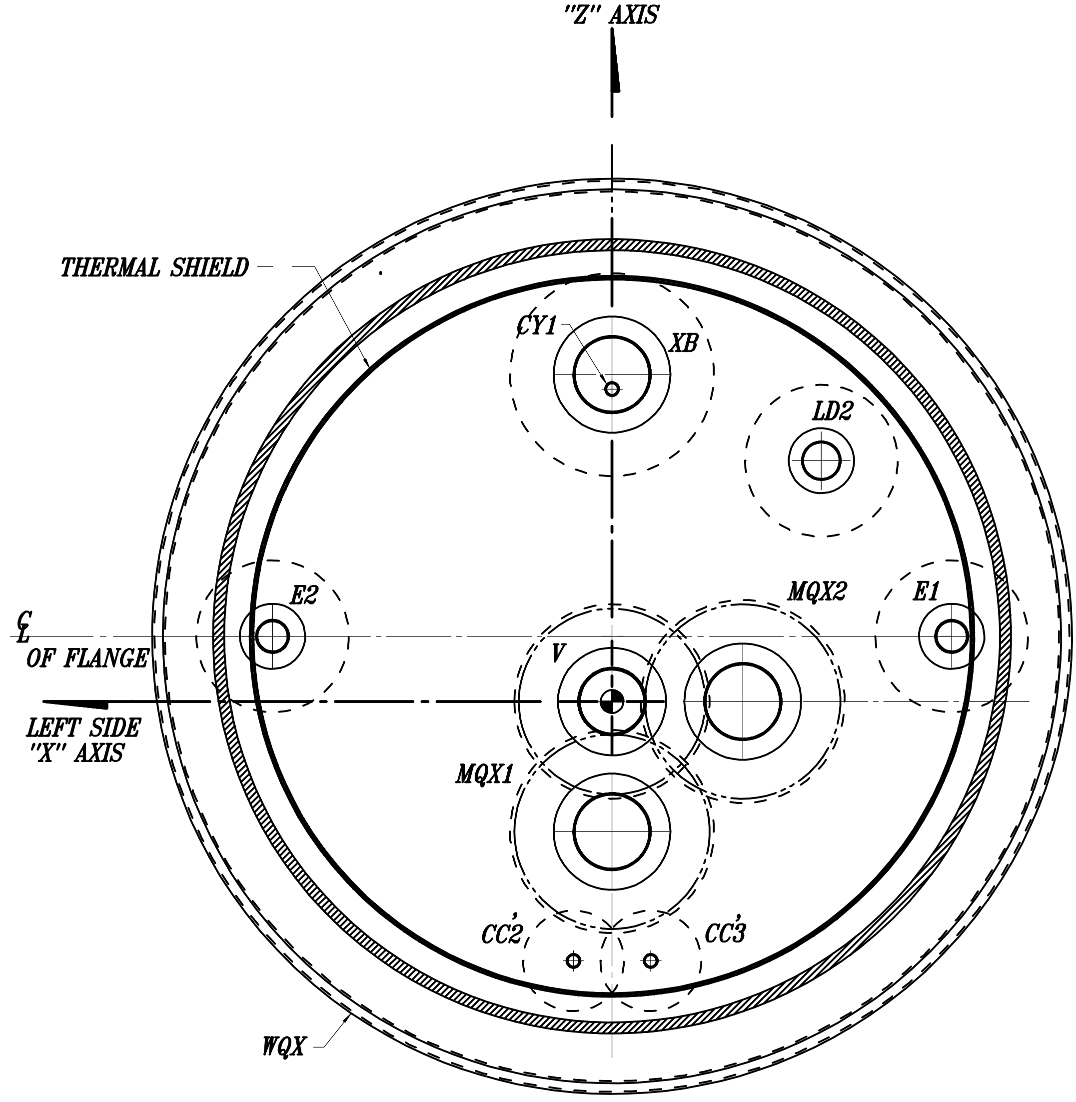



**Figure 6.4.3-2. DFBX (low-side) 50-mm automatic orbital welder clearance envelopes shown as dashed lines between flanged pipe ends for piping weld connections at interconnect plane. 45-mm clearance also shown for V, MQX1 and MQX2. (Thermal shield does not extend into interconnect region.)**

## 5.5 THERMAL SHIELD BRIDGE CONNECTION DETAILS

The DFBX copper thermal shield extends from the end-face of the vacuum box flange by 38 mm, and is centered about the axis of the flange. The OD of the DFBX thermal shield diameter is 830 mm. The LQXC thermal shield is centered about the cryostat axis and extends 50 mm beyond the LQXC flange on the DFBX side. The thermal shield bridge will be fabricated in two parts, upper and lower halves, bolted together over the piping in the interconnect region using a clam shell design. The overall length of the shield bridge is 500 mm. The bridge will be fixed longitudinally to the LQXC shield and slide over the DFBX shield.

## 5.6 VACUUM VESSEL CONNECTION DETAILS

### 5.6.1 SEALING FLANGE

The sealing flanges on the DFBX and the LQXC contain O-rings. The groove details for the DFBX flange are shown on the transverse planar section drawings [j] through [q]. These designs are based on the CERN design used elsewhere on the LHC and will, alternately, allow the use of helicoflex metal seals instead of O-rings.

The LQXC employs a CERN vacuum vessel bellows and groove details identical to those used on the LHC arc dipoles. Details for the LQXC are shown on the vacuum vessel bellows and sliding flange weldment [r].

### 5.6.2 STRUTS FOR VACUUM LOADING

Four tie bars (diameter M30) will be used to transfer the axial vacuum load from the LQXC to the DFBX. They are secured with double nuts and spherical washers which allow the rotation of the tie rods for alignment of the LQXC cryostat and DFBX vessel under vacuum. Brackets on the face of the DFBX box outboard of the flange, and on the circumference of LQXC cryostat flange, are located at ±45 and ±135 degrees off the LQXC vacuum vessel centerline. The effective bolt circle for the four tie bars is 1250 mm (diameter). The DFBX box will be secured to the floor when installed using three tie down brackets designed to allow vertical adjustment of the support jacks while resisting axial loads to accommodate alignment under vacuum. See LHC-DFBX-ES-260 for details [5].

# 6. ELECTRICAL INTERFACES

## 6.1 MAGNET BUSSES AND DIAGNOSTICS

The main and corrector magnet busses, which are carried in line MQX1, are listed in Table 7.1-1. The magnet diagnostic [2] cables, which are carried in line MQX2, are listed in Table 7.1-2. All busses and diagnostic wires are Kapton insulated and will be labelled to specify their functionality and polarity. The free length of the main quadrupole busses are set to allow a splice of length greater than the cable transposition length of 114±5 mm to be made within the space provided by the compressed bellows. The length provided for the corrector busses and the diagnostic leads is greater than that required for their splices, allowing them to be cut to the appropriate length at installation. All connections require strain relief support as specified in LHC-QI-ES-0001 [6].

Test voltages for the busses are specified in the relevant Functional Specifications [2,8,9,10,11]. The test voltages specified for the diagnostic cables in Table 7.1-2 apply to the leads within the DFBX. Test voltages on the LQXC side are specified in the appropriate magnet Functional Specification [2,9,10,11].

**Table 7.1-1 Power Busses in pipe MQX1. The bus lengths are measured with respect to the origins of the local coordinate systems of the DFBX and LQXC respectively.**

| Item | Insulated Bus Area (mm x mm) | No. of Busses | Free Length (mm) | | Lead[a] Designation |
|---|---|---|---|---|---|
| | | | DFBX | LQXC | |
| Q1 – Q3 Power Bus (+ and -) | 16.5 x 3.6 | 1 pair | 240 | 430 | P3, P4 |
| Q2 Trim Bus (+ and -) | 16.5 x 3.6 | 1 pair | 240 | 430 | P1, P2 |
| 600 A Corrector Bus | 2.5 x 1.7 | 14 (7 pair) | 240 | 430 | A2n, Hmn, Vmn |
| 120 A Corrector Bus | 2.5 x 1.7 | 10 (5 pair) | 240 | 430 | Ajn, Bkn |

a. Lead subscripts are as follows: "n" is A or B, "m" is 1, 2, or 3, "j" is 3 or 4, and "k" is 3, 4, or 6. See Fig. 7.2-1.

**Table 7.1-2 Diagnostic Cables in pipe MQX2. Test voltages apply to the DFBX only. The cable lengths are measured with respect to the origins of the local coordinate systems of the DFBX and LQXC respectively.**

| Item | Cable Type | AWG | No. of Cables | Test Voltage [7] | Free Length (mm) | | Wire Designation/ Color (1 – 4) |
|---|---|---|---|---|---|---|---|
| | | | | | DFBX | LQXC | |
| Quad Voltage Taps | 2-wire | 26 | 12 | 1400 | 240 | 430 | $V_i$ (i=1-4) / 1 |
| Quench Heaters | 2-wire | 18 | 8 | 1400 | 240 | 430 | $H_i$ (i=1-10) / 4 |
| Temp Sensors | 4-wire | 30 | 8 | 200 | 240 | 430 | $T_i$ (i=1-32) / tbd |
| Corrector Voltage Taps | 1-wire | 26 | 12 | 1400 | 240 | 430 | $C_i$ (i=1-12) / 2 |
| Cryo Heaters | 2-wire | 18 | 8 | 1400 | 240 | 430 | $W_i$ (i=1-16) / 3 |

## 6.2 MAIN AND CORRECTOR MAGNET BUS BARS

The DFBX bus bars that provide main and corrector magnet powering are contained in the duct designated MQX1. A cross-sectional view of the bus as they exit the lambda plate is shown in Figure 7.2-1. A longitudinal view of the bus connection at the interconnect region is shown in Figure 7.2-2.

The leads within the DFBX are fixed to the MQX1 pipe at the lambda plate, and the MQX1 pipe is fixed to the LHe chamber. Thus the fixed point for the bus bars in the DFBX is the midplane of the LHe chamber, located approximately 1435 mm from the interconnect plane.

The bus is supported within the MQX1 pipe in the LQXC by a spider, which has holes to allow helium to pass through. The spider constrains the bus bars in the transverse direction but allows longitudinal movement for thermal contraction. Thermal contraction will be taken an expansion loop in the LQXC as there is little flexibility in the DFBX bus.

In Fig. 7.2-1 the corrector busses are labelled according to their function and, where appropriate, location. Busses labelled Hn or Vn correspond the horizontal or vertical dipole correction windings in the MCBX(A) corrector attached to the Qn quadrupole, where n = 1, 2, or 3. Busses labelled A2 correspond to the skew quadrupole windings in the MQSXA corrector. Busses labelled An or Bn correspond to the $a_n$ or $b_n$ multipole correction windings inside the MCBXA or MQSXA correctors. See [11] for the layout of the correction system.

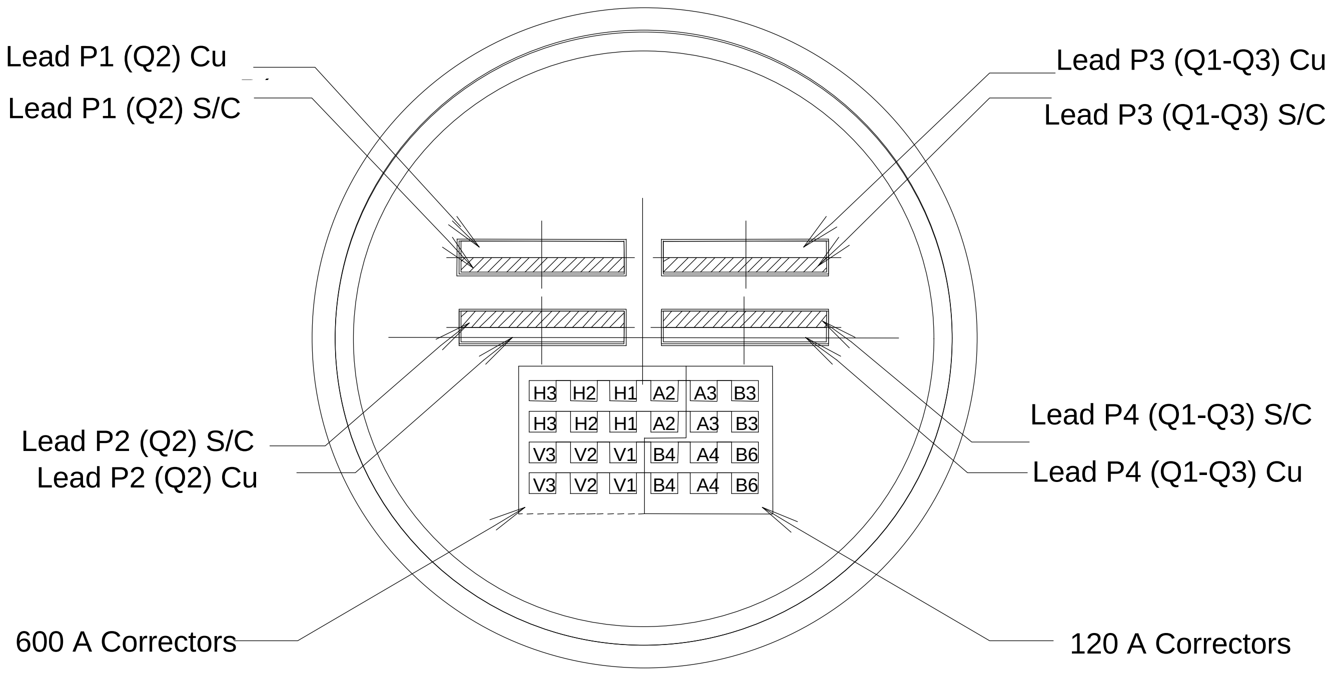



**Figure 7.2-1. Cross-sectional view of the bus inside the DFBX looking towards the DFBX from the Q3. For each pair of corrector leads, the "A" lead is above the "B" lead.**

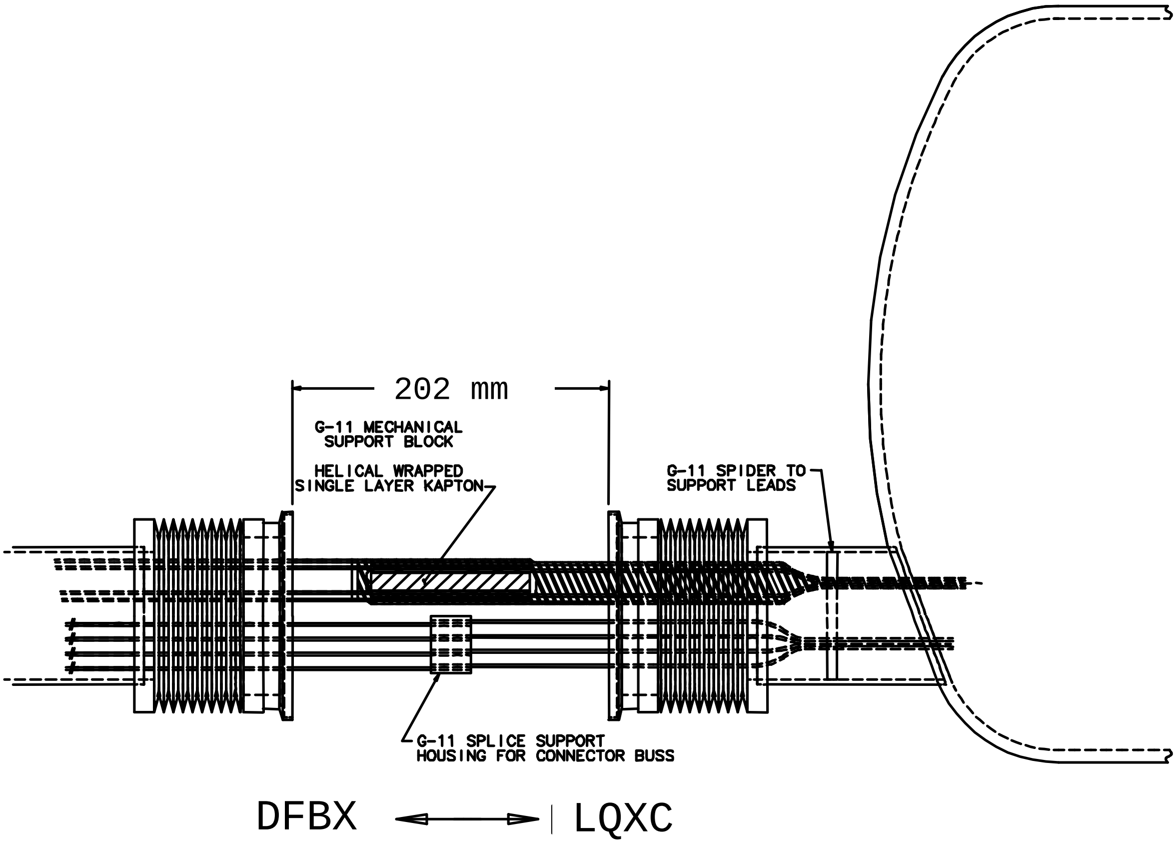



**Figure 7.2-2. Longitudinal view of DFBX to LQXC bus at the interconnect region.**

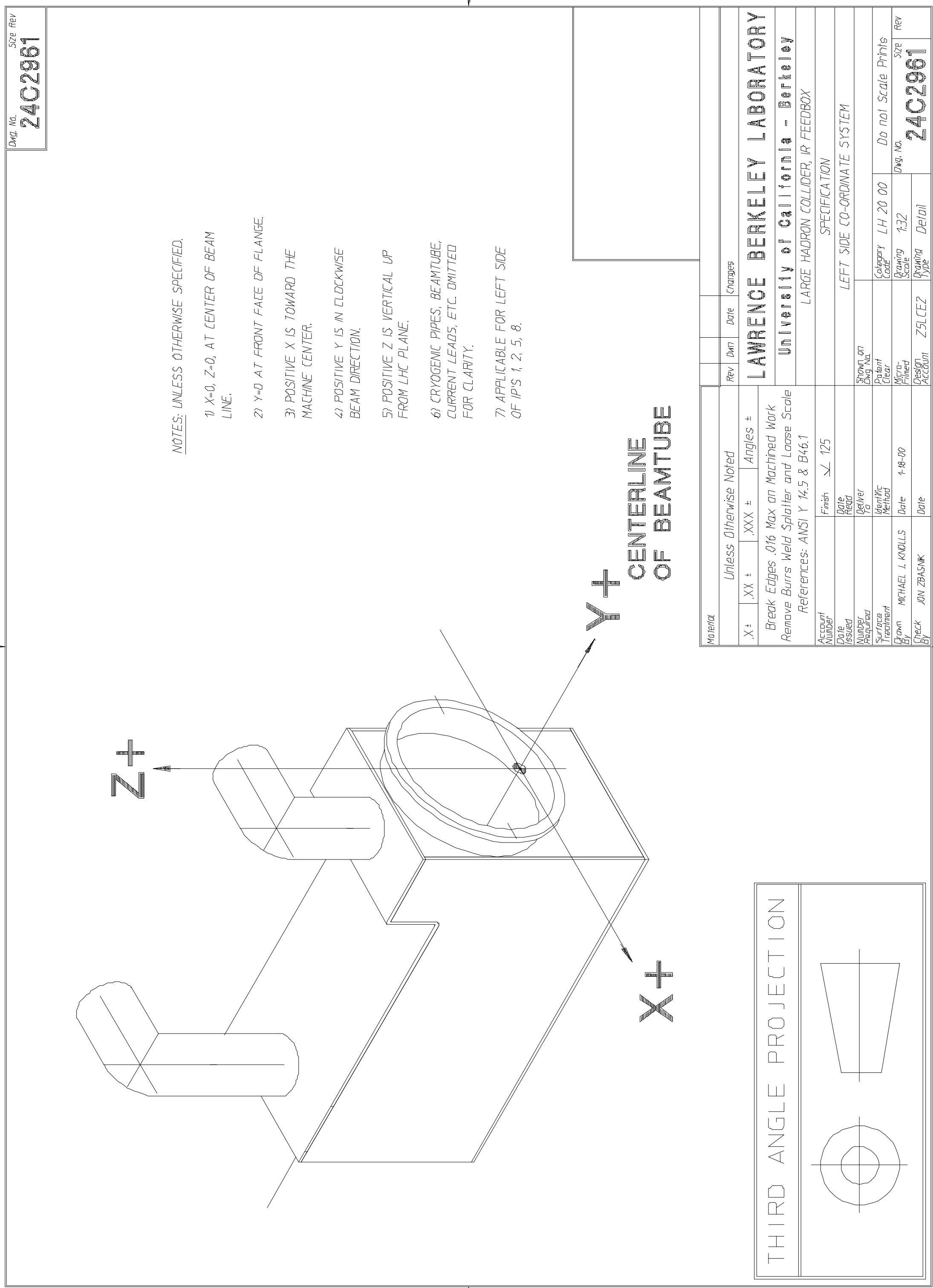
# 7. DRAWINGS

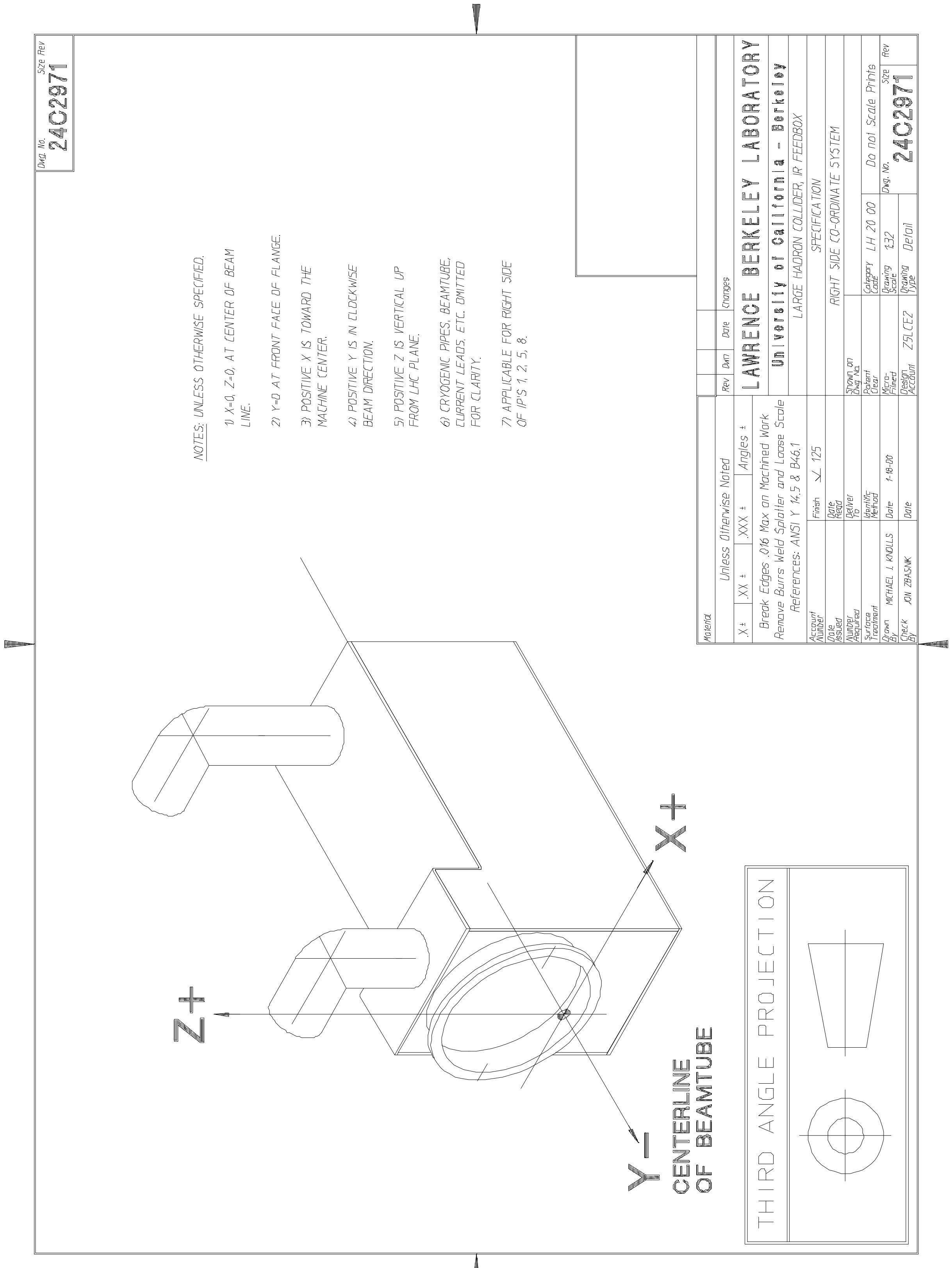
a. LHCLSX_0001D, LAYOUT OF LSS V.6.2 – IR1 LEFT, 21 August 2000.
b. LHCLSX_0002D, LAYOUT OF LSS V.6.2 – IR1 RIGHT, 21 August 2000.
c. LHCLSX_0003D, LAYOUT OF LSS V.6.2 – IR2 LEFT, 21 August 2000.
d. LHCLSX_0004D, LAYOUT OF LSS V.6.2 – IR2 RIGHT, 21 August 2000.
e. LHCLSX_0009D, LAYOUT OF LSS V.6.2 – IR5 LEFT, 21 August 2000.
f. LHCLSX_0010D, LAYOUT OF LSS V.6.2 – IR5 RIGHT, 21 August 2000.
g. LHCLSX_0015D, LAYOUT OF LSS V.6.2 – IR8 LEFT, 21 August 2000.
h. LHCLSX-0016D, LAYOUT OF LSS V.6.2 – IR8 RIGHT, 21 August 2000.
i. LHCDFBX_0001, Distributive Feedbox Schematic, LBNL 24C3706.
j. LHCDFBX_0004, DFBX Connections to Q3 at IR1L, LBNL 24C2996.
k. LHCDFBX_0002, DFBX Connections to Q3 at IR1R, LBNL 24C2986.
l. LHCDFBX_0006, DFBX Connections to Q3 at IR2L, LBNL 24C3006.
m. LHCDFBX_0008, DFBX Connections to Q3 at IR2R, LBNL 24C3016.
n. LHCDFBX_0003, DFBX Connections to Q3 at IR5L, LBNL 24C2986.
o. LHCDFBX_0005, DFBX Connections to Q3 at IR5R, LBNL 24C2996.
p. LHCDFBX_0007, DFBX Connections to Q3 at IR8L, LBNL 24C3006.
q. LHCDFBX_0009, DFBX Connections to Q3 at IR8R, LBNL 24C3016.
r. LHCLQXI_XXXX, LHC-IRQ Cryostat Q3-Q2 Interconnection, Layout cross-section Views, FNAL 5520-ME-390XXX.
s. LHCLQXI_0001, LHC IRQ Cryostat Cold Down Bellows, FNAL 5520-MC-390061.
t. LHCLQXI_0002, LHC IRQ Cryostat Cold Mass Bellows Assembly, FNAL 5520-MB-390073.
u. LHCLQXI_0003, LHC IRQ Cryostat Pumping Line Bellows, FNAL 5520-MC-390065.
v. LHCLQXI_0004, Sliding Bellows Closure and Flange Assembly, FNAL 5520-ME-390021.
w. LHCLQXI_0005, Pumping Line and Cold Mass Connection Flange, FNAL 5520-MC-390032.
x. LHCLQXI_0006, Cool Down Line End Flange, FNAL 5520-MB-390033.
y. LHCLQXI_0007, Shield Line End Flange, FNAL 5520-MB-390035.
z. LHCLQXI_0008, Heat Exchanger Corrugated Tube End Flange, FNAL 5520-MB-390030.
aa. LHCLQXI_XXXX, Flange Weld Rings, FNAL 5520-XX-XXXXXX.
bb. LHCLQXI_0010, Shield Line Bellows Assembly, FNAL 5520-MD-390056.

# 8. REFERENCES

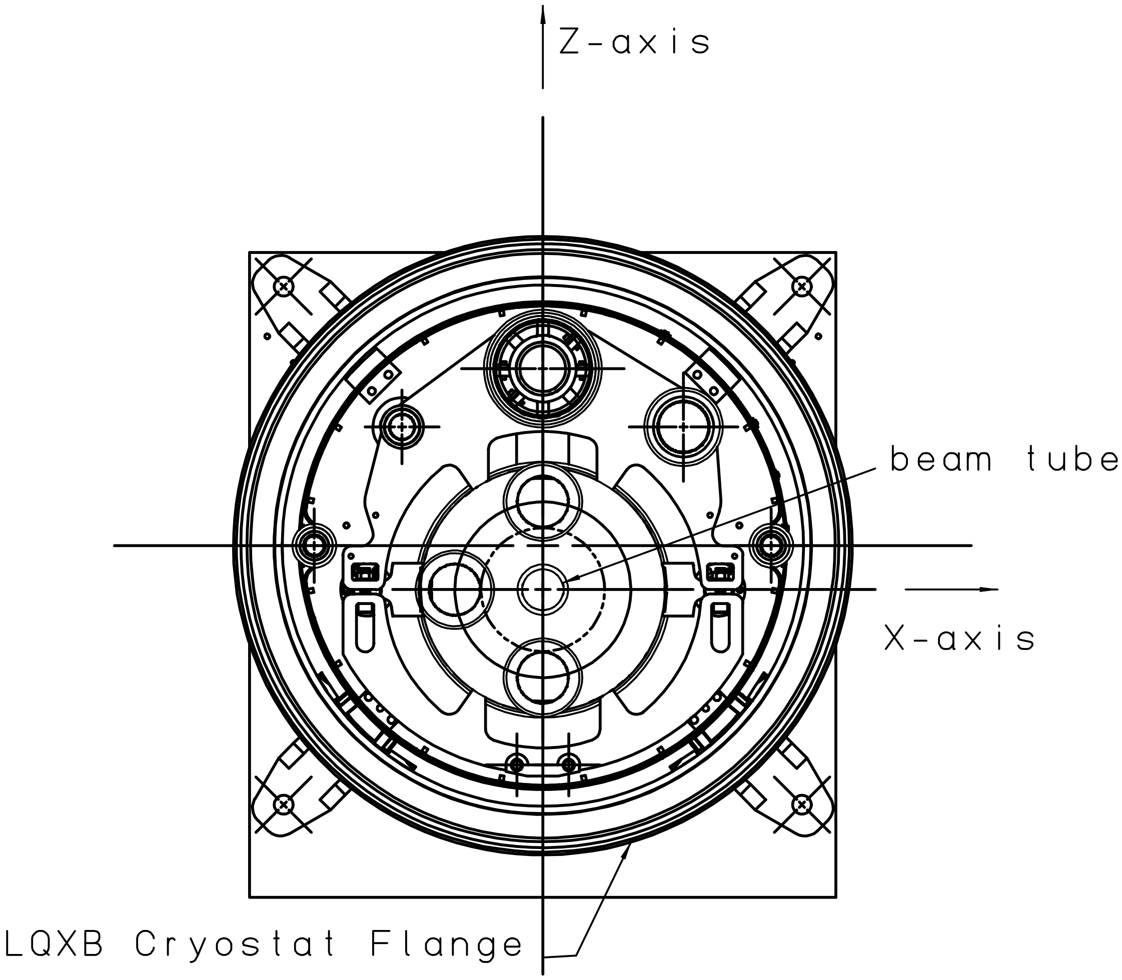
1. LHC Interface Specification, "Inner Triplet Feedboxes General Interfaces," LHC-DFBX_-ES-0200.00.
2. LHC Functional Specification, "Inner Triplet Quadrupole MQXB," LHC-LQX-ES-0002.
3. LHC Interface Specification, "DFBX to QRL," LHC-DFBX_-ES-0240.00.
4. LHC Interface Specification, "Inner Triplet Feedboxes: DFBX - Beam Tube," LHC-DFBX_-ES-0220.00.
5. LHC interface Specification, "DFBX – Tunnel and Alignment Interface," LHC-DFBX_-ES260.00.
6. LHC Engineering Specification, "Instrumentation Wires, Connection Techniques and Feedthroughs for the Main Arc LHC Cryomagnets and the QRL," LHC-QI-ES-0001 rev 2.0, 27 September 2000.
7. LHC Engineering Specification, "Voltage Withstand Levels for Electrical Insulation Tests on Components and Bus Bar Cross Sections for the Different LHC Machine Circuits," LHC-PM_-ES-0001 rev 1.1, 31 August 2000.
8. LHC Functional Specification, "Inner Triplet Feedboxes, DFBX," LHC-DFBX-ES-0100.00.
9. LHC Functional Specification, "Inner Triplet Quadrupole MQXA," to be written.
10. LHC Functional Specification, "Inner Triplet Corrector MCBX," to be written.
11. LHC Functional Specification, "Inner Triplet Corrector MQSXA," to be written.
12. LHC Functional Specification, "Inner triplet systems at IR1, 2, 5 and 8," LHC-LQX-ES-0001.00.

# 9. APPENDIX A – DEFINITION OF DFBX LOCAL COORDINATES


Dwg. No. 24C2961 Size Rev
NOTES: UNLESS OTHERWISE SPECIFIED.
1) X=0, Z=0, AT CENTER OF BEAM LINE.
2) Y=0 AT FRONT FACE OF FLANGE.
3) POSITIVE X IS TOWARD THE MACHINE CENTER.
4) POSITIVE Y IS IN CLOCKWISE BEAM DIRECTION.
5) POSITIVE Z IS VERTICAL UP FROM LHC PLANE.
6) CRYOGENIC PIPES, BEAMTUBE, CURRENT LEADS, ETC. OMITTED FOR CLARITY.
7) APPLICABLE FOR LEFT SIDE OF IP'S 1, 2, 5, 8.
Z+
Y+
X+
CENTERLINE OF BEAMTUBE
THIRD ANGLE PROJECTION
Material
Unless Otherwise Noted
.X ± .XX ± .XXX ± Angles ±
Break Edges .016 Max on Machined Work
Remove Burrs Weld Splatter and Loose Scale
References: ANSI Y 14.5 & B46.1
Account Number
Date Issued
Number Required
Surface Treatment
Drawn By MICHAEL J. KNOLLS Date 1-18-00
Check By JON ZBASNIK Date
Finish 125
Date Reqd
Deliver To
Identific Method
Rev Dwn Date Changes
LAWRENCE BERKELEY LABORATORY
University of California - Berkeley
LARGE HADRON COLLIDER, IR FEEDBOX
SPECIFICATION
LEFT SIDE CO-ORDINATE SYSTEM
Shown on Dwg. No.
Patent Clear
Micro-Filmed
Design Account Z5LCE2
Category Code LH 20 00
Drawing Scale 1:32
Drawing Type Detail
Do not Scale Prints
Dwg. No. 24C2961 Size Rev


Dwg. No. 24C2971 Size Rev
NOTES: UNLESS OTHERWISE SPECIFIED.
1) X=0, Z=0, AT CENTER OF BEAM LINE.
2) Y=0 AT FRONT FACE OF FLANGE.
3) POSITIVE X IS TOWARD THE MACHINE CENTER.
4) POSITIVE Y IS IN CLOCKWISE BEAM DIRECTION.
5) POSITIVE Z IS VERTICAL UP FROM LHC PLANE.
6) CRYOGENIC PIPES, BEAMTUBE, CURRENT LEADS, ETC. OMITTED FOR CLARITY.
7) APPLICABLE FOR RIGHT SIDE OF IP'S 1, 2, 5, 8.
Z+
X+
Y−
CENTERLINE OF BEAMTUBE
THIRD ANGLE PROJECTION
Material
Unless Otherwise Noted
.X ± .XX ± .XXX ± Angles ±
Break Edges .016 Max on Machined Work
Remove Burrs Weld Splatter and Loose Scale
References: ANSI Y 14.5 & B46.1
Finish 125
Account Number
Date Issued
Date Reqd
Number Required
Deliver To
Surface Treatment
Identific Method
Drawn By MICHAEL L. KNOLLS Date 1-18-00
Check By JON ZBASNIK Date
Rev Dwn Date Changes
LAWRENCE BERKELEY LABORATORY
University of California - Berkeley
LARGE HADRON COLLIDER, IR FEEDBOX
SPECIFICATION
RIGHT SIDE CO-ORDINATE SYSTEM
Shown on Dwg No.
Patent Clear
Micro-Filmed
Design Account Z5LCE2
Category Code LH 20 00
Drawing Scale 1:32
Drawing Type Detail
Do not Scale Prints
Dwg. No. 24C2971 Size Rev

# 10. APPENDIX B – DEFINITION OF LQXC LOCAL 2D - COORDINATES




2D Reference Axes for LQXB

(LQXC Cryostat Flange as seen from the DFBX vacuum vessel.)